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TO COMMEMORATE THE CENTENARY OF THE BIRTH OF KONSTANTIN CIOŁKOWSKI

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"In many instances I can only foretell or prophesy. I have no doubt and know perfectly well that I am not solving the whole of the problem, that it will take 1000 times more work by others than I did. My goal is to arouse interest, stressing the great importance of the problem in the time to come and the possibility to have it solved....."

This has been written by the great Russian scientist Konstantin Ciołkowski in 1903 in his first work on astronautics that was published and it was the first scientific work of importance on astronautics in the whole world. It bore the title: *Investigation of the world space by means of instruments propelled by jet device* [1].

Ciołkowski was born on the 17th of September 1857 in a small country village in the government of Riazan where his father Edward was a forester. It has been confirmed by Ciołkowski himself in a letter addressed to the well known Cracow astronomer Banachiewicz [2] that his father was of Polish origin, who in his early years settled down in Russia and married a Russian girl. When 9 years, of age Ciołkowski lost almost completely his hearing due to compli-

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[1] K. E. Ciołkowski (in English transcription Tsiolkovski or Ziolkovsky). *Sobranie sotchinienii (Collected Works)*, vol. II, Moscow 1954, p. 79.

[2] The original letter bearing the date July 10th 1931 is in the collection of the Astronomical Observatory in Cracow. Its translation reads: "From Ciołkowski to prof. Banachiewicz: My deeply respected Thadee Arthurowitsch. My father is indeed your countryman: a catholic from Wolhynia. But already in his youth he was brought up in USSR and married here a Russian girl. Thanks for the letter and for your article. I am sending you some of my pamphlets. Yours truly K. Ciołkowski. P. S. You made no error in my name. USSR. Kaluga. Brut 79 (address)".

cations derived from scarlet fever and deafness forced him to cancel his school education. The early years of this scientist have been a period when the perseverance and will-power conquered his deafness, when his solitary meditations over books, primarily at home and later in libraries in Moscow, where his father sent him as a 16 years old boy for education, enabled him not only to pass an examination for a teacher's diploma, but to acquire a thorough knowledge of higher mathematics and of exact sciences. In 1879 Ciołkowski became a teacher first in Borowsk, a county village in the government of Kaluga, and many years later in Kaluga itself. He remained in Kaluga for the rest of his life and devoted all his time free from teaching duties to scientific work. He died in full glory of fame and recognition, enjoying in the late years a care of the Soviet authorities, on 19th September 1935.

The personal biography of Ciołkowski is very scarce, his scientific biography however is very abundant.

In 1881 when only 24 years of age he sent his first scientific work to the Petersburg Physico-Chemical Society. It dealt with kinetic theory of gases and contained the right conclusions, which were arrived at by Ciołkowski independently, though they were already known to science for about 25 years. Nevertheless this work was duly appraised and Ciołkowski received a letter from the great chemist Mendeleyeff on behalf of the Society encouraging him to proceed with his work. Soon after Ciołkowski was elected member of the said society.

At that stage the chief trends in Ciołkowski's scientific and technical studies became clearly defined. The one in aerodynamics and aviation, the other — in the mechanics of rocket propulsion, rocket technology and astronautics.

The first work of Ciołkowski dealing with aviation has been written in 1885. It was a scheme of a dirigible with a metallic cover. His next work *The problem of flying with the aid of wings* was wholly devoted to aerodynamics. This work also is in need of scientific foundation. The author himself wrote two years later: "This work has been written in such a spirit as if previously nothing was done in that matter. Indeed having no library in my solitude I had to work quite independently, not counting the most elementary scientific foundations. Later professor Żukowski recommended me a number of works whose inferences were similar to mine. The laws

however determining the dependence of fluid pressure from the elongation of the wings are something new in science" [3].

A work of this kind would be of no value were it not supported by experiments. Ciołkowski, who beside his scientific problems was very deeply involved in discoveries, excelled in experimentation. All apparatuses, very simple and ingenious, were built by himself. The necessary material was purchased by Ciołkowski out of his very moderate earnings.

For a long time Ciołkowski's experiments were done in natural conditions, in calm weather (or in a closed room) and taking advantage of natural winds. In 1897 Ciołkowski constructed an aerodynamic tunnel, the first in Russia, and was able to apply an artificial air current. At the same time he designed aerodynamic scales of great precision. With the help of this equipment he performed a number of experiments defining air resistance and the bearing forces of bodies of various shapes, especially of wing models and dirigibles.

The results of these experiments were published by Ciołkowski in 1898 in a work entitled *Air pressure on surfaces introduced to an artificial air current.* This article of some tens of pages may be considered one of the basic works on experimental aerodynamics. Among other problems which were solved here we find such as the effect of wings elongation on their aerodynamic characteristic, the effect of the dimensions of the body's surface and of the velocity of the current on the degree of friction a.s.f.[4].

The work of Ciołkowski was highly appreciated by M. A. Rikatcheff, member of the Russian Academy of Sciences and the Academy granted him a subsidy of 470 roubles. It was the only financial assistance received by Ciołkowski for his scientific studies in the prerevolutionary period, not counting the 55 roubles collected for his research work by a Russian scientific periodical.

This subsidy enabled Ciołkowski to perfect his aerodynamic tunnel and to make a number of further experiments. These experiments confirmed the results obtained previously and furnished

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[3] From remarks by Ciołkowski in 1893 concerning his work *The problem of flight by means of wings.* Quotation taken from a foreword to the I volume of the collected works of Ciołkowski. Moscow—Leningrad 1951, p. 7.

[4] Compare article by N. J. Fabricant: *On the works of K. E. Ciołkowski in the domain of aerodynamics* in vol. I of the above named edition of the collected works of Ciołkowski, p. 12.

material to draw further inferences. To the end of his life Ciołkowski often went back to the problems of aviation and aerodynamics.

Ciołkowski's work, a very real contribution to aerodynamics, although often undervalued, is not his chief claim to fame. Fame came to him as the result of his important works dealing with mechanics of rocket motion, rocket technology and astronautics.

At the end of the XIX century the rocket technology had already a long and rich history. But it was only at that time that the idea of applying a rocket engine to cosmic flights was born and it was on the verge of the XIX and XX centuries that the mechanics of rocket motion have been devised.

In both these domains Ciołkowski's contribution has been a deciding factor, though he was not the author of the first design of a cosmic ship propelled by a rocket. The author of such a design [5] was a German inventor, Hermann Ganswindt [6].

In a lecture delivered in Berlin in 1891 Ganswindt described his cosmic ship. By means of a series of consecutive explosions in the combustion chamber of such a ship heavy steel cartridges had to be ejected. The thrust of these cartridges was intended to put the rocket in motion. This device enabled the Ganswindt's engine to work in a cosmic vacuum. Ganswindt idea found some publicity in the German and Austrian press [7] but had no scientific foundation. The modern rocket and the contemporary projects of cosmic travels have nothing in common with the Ganswindt design but the idea to use jet as a propelling force in vacuum.

To lay solid foundations under astronautics it was necessary to have men who combined vision with a scientific background and with an ability for a steady and forceful work. The first of such men was Ciołkowski.

The idea of cosmic flight was deeply rooted in his mind since his boyhood. The first notices concerning motion in a gravitation free space bear the date 1878, when the author was 20 years old.

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[5] Already in 1865 in a novel *A trip to Venus* published in Paris Achille Eyraud described a cosmic flight aboard a ship propelled by a rocket engine, whose idea was however entirely false.

[6] The life story of Ganswindt is given by W. Ley in his work: *Rockets, Missiles and Space Travel*, New York 1951, p. 91–100.

[7] It may be worth to notice that professor at the Lwow Polytechnic School Roman Gostkowski published in 1900 in a Viennese periodical „Die Zeit" an article critisising the idea of Ganswindt. This article is the first or one of the first in which a scientist states his opinion on astronautics and certainly the first item in the Polish literature on astronautics.

A bigger unfinished work under the title *Free space* preserved in manuscript, has been written in 1883 [8]. Ciołkowski deals here with the laws governing motion in gravitation free space, with the behaviour of some physical instruments in such a space and the conditions under which plants and animals may subsist.

In this work Ciołkowski gives an account of the principles of rocket motion in a gravitation free space. "Let us suppose a barrel full of heavily compressed gas. Let us open a faucet at this barrel. Gas will be ejected out of the barrel with a steady stream and the elasticity of gas ejecting its particles into space will at the same time push steadily the barrel backwards. The result will be a continuous change in the barrel's motion" [9].

Ciołkowski did not consider then a rocket to be a means for a cosmic flight and seeing no way for the realization of his dreams ceased to work in this direction.

He came back to the problem of astronautics after many years, which he devoted to the problems of aerodynamics and aviation. In 1893 he wrote a fanciful story *On the moon*. Since 1896 he became convinced to the adaptability of rockets to astronautics and began to work systematically on the mechanics of rocket motion and on the adaptability of rockets to cosmic travels.

The result was a book mentioned in the beginning *Investigation of the world space by means of instruments propelled by jet device*. The publication of this work in 1903 may be considered as the birth of astronautics as a technical and scientific discipline.

In the next 32 years Ciołkowski worked without interruption on astronautical problems. During this time we see his scientific works appear regularly, beside fantastic stories and popular works. Fantasy is an inseparable companion of Ciołkowski. In almost all his scientific works beside an exact mathematical analysis there is always a bold projection into the future, to the time when mankind will be able to travel in universe.

In one of his works (in 1911) he wrote: „The better part of mankind will probably never perish, but will migrate from sun to sun faced with extinction. After many decylions of years we will

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[8] This work has been published for the first time in the above named edition of collected works by Ciołkowski, vol. III, p. 25–68.

[9] Ibidem, p. 52.

be living maybe on a sun that at present does not even shine, but exists merely in embryonic state as a nebulous matter" [10].

Ciołkowski is however well aware that the road to the realization of this fantasy requires an enormous amount of scientific and theoretical work and knows that his lot is only to lay the foundations to this work.

Ciołkowski saw clearly the complexity and manysidedness of astronautic problems and turned his interest in many directions, theoretical, scientific and technical. He saw the necessity to work out a theoretical foundation of the principles of rocket motion and at the same time to solve some extremely difficult technological and construction problems concerning the cosmic rockets, finally the necessity to explore the conditions of man's life in cosmic space.

Already in his work of 1903 Ciołkowski came to a basic equation of rocket motion. At the end of the XIX century Russian science was engaged in the research on the motion of bodies of a variable mass and in 1897 appeared a book by I. M. Meshtchersky, a basic work entitled *Dynamics of a point at a variable mass*. It was Ciołkowski however who worked out the equations of the motion of rockets starting from the earth surface or from some other celestial body into cosmic space.

Analysing this problem Ciołkowski applied the method of consecutive approximations. He begins with an equation of rockets motion in an empty free of gravitation space, then takes into account the effect of gravitation and into his deliberations brings finally the force of air resistance. He comes to a hypothesis which is now universally recognized, that the relative velocity of combustion gases ejected from a rocket is a constant.

For a gravitation free space Ciołkowski introduces on such a basis the well known formula

$$v_p = w \ln \frac{m_o}{m_k}$$

where v_p means the velocity of the rocket at a given moment, w — the relative velocity of the ejection of the combustion gases, m_o — the initial mass of the rocket, that is its mass together with the mass of the fuel added, m_k — the mass of the rocket at a given moment, that is after the velocity v_p has been reached.

[10] Ibidem, p. 139

This formula indicates that the maximum velocity attained by a rocket may be increased in the first place through an increase in the velocity of the gases ejection. The increase in the quantity of fuel, that is the decrease in the relation of the useful and constructional mass to the mass of fuel, has much less effect on the increase of rockets speed.

From the point of view of cosmic flights the maximum speed of the rocket is the deciding factor. To overcome the force of gravity and to reach a point at a given distance from the earth it is absolutely necessary for the rocket to attain a certain speed. Such speed, named flight speed for the earth according to a calculation by Ciołkowski is equal to 11170 meters per second.

Being aware that the velocity of ejected combustion gases is of utmost importance to the realization of cosmic flights Ciołkowski devotes special attention to the selection of proper fuels. One year before his death [11] he devotes a special article to this question. Reviewing all kinds of fuels he points to the merits of liquid fuels and takes into account the possibility to use liquefied gases and powders.

Ciołkowski's work is not restricted to an analysis of means accessible by the contemporary state of science and technology. His thought rises continuously into the domain of scientific fantasy whose really wonderful foresight we are capable to appreciate only to-day, or may-be it will be possible only to-morrow. In a paragraph bearing the characteristic title *Dreams* written in 1911 he quotes velocities attained by the products of radium desintegration and writes further:

"If it were possible to accelerate sufficiently the desintegration of radium or other radiating elements, and such are probably all bodies, then the use of such one would convey.... such a velocity to the rocket that the time needed to reach the nearest sun would be cut to 10-40years. In such a case a pinch of radium would be enough for the rocket to break all bonds with the solar system" [12].

In another of his works written in 1924 Ciołkowski points to the possibility (though he considers it in a hypothetical way only) to transfer to the cosmic ship an additional energy from the earth in

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[11] *The conquest of atmosphere. The fuel of the rocket.* Above named edition of Ciołkowski collected works, vol. II, p. 368-376.

[12] Ibidem, p. 136.

the form of electromagnetic radiation whose pressure would act as an accelerator [13].

A more realistic conception was an idea that has been since realized and whose origin may be traced to a work by Kazimierz Siemienowicz written 300 years before which in all probability Ciołkowski did not know [14]. Being conscious that the kinds of fuel available at that time were not able in an ordinary way to make a cosmic flight possible Ciołkowski in 1919 conceives the idea to build a multistage rocket. In the same fantastic story *Beyond the Earth* [15] we find an idea of an artificial satellite, the first of which has been launched by Soviet scientists almost exactly in the centenary of Ciołkowski's birth.

Many constructional ideas of Ciołkowski have a practical value, such is the introduction of stabilizers to the ejection nozzle, later applied by von Braun in the German rocket V-2 in the shape of internal vanes made of graphite [16].

Ciołkowski is a perfect example of a scientist who unites theoretical research with practical invention. In the year 1926 he wrote the following:

"The idea, fantasy, fairy-tale must come first. Then comes the scientific calculation. The realization of the idea is the final crowning point. My writings of cosmic travels belong to the second phase of the creation field. I am perfectly conscious, more than anyone else, of the immense abyss that separates an idea from its realization. In my whole life I was not only thinking and calculating, but assisting the realization of the idea, by working with my own hands" [17].

In his studies of the biological conditions of cosmic fights Ciołkowski was in want of such practice in experimentation. These chapters of his works therefore which are devoted to the waning of gravitation, to the effect of great accelerations are rather superficial. They are however of value to the history of astronautics as many of its problems have been raised for the first time namely by Ciołkowski.

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[13] Ibidem, p. 158–9.

[14] Compare an article by M. Subotowicz, *Kazimierz Siemienowicz and his contribution to the rocket science* in this here number.

[15] Edited in Kaluga in 1920.

[16] Compare the above quoted work by W. Ley, p. 193–4.

[17] Above named edition of Ciołkowski works, vol. III, p. 180.

The plan for astronautic work and astronautic research elaborated more than once by Ciołkowski shows clearly the way his mind worked. In an article written in 1926 such a plan contains 16 items [18]. The first items were supposed to be realized in a few years and in the last thirty years this has been done. They dealt with the construction of a rocket aeroplane, capable to attain higher and higher altitudes, and with the construction of artificial satelites. Further points provided for the construction of bigger satellites which should serve as service stations and await still their realization. The last items reach into still further space and a still further future. They deal with the utilization of solar energy for travels throughout the whole solar system, for establishing colonies on planetoids and founding industries there, for travels beyond the solar system. Item N. 16 reads: "The extinction of the sun has begun. People living still in the solar system migrate to other suns, to their brethren who emigrated there previously".

How characteristic of Ciołkowski is such a transition from purely technical deliberations to a scientific fantasy! How the lack of educational training had a positive effect on the inventive thought of Ciołkowski, his lack of routine, not scientific maybe, but that of a professor. Only at another selftaught man of genius we may find a similar analogy and such a bond between reality and fantasy — at Leonardo da Vinci.

For many years the work and ideas of Ciołkowski were known only to a small circle of Russian patrons of aviation. It was only just before the first world war, due mostly to the efforts of J. I. Perelman, who was interested in the popularization of science, that the name of Ciołkowski and his ideas became well known in Russia. The works of a teacher in Kaluga were not accessible to foreign scientists to whom Russian language was unknown. The war and the first revolutionary years were not favourable to the works of Ciołkowski being disseminated.

Meanwhile some research workers and inventors in different countries started to work on the problems of astronautics. In France Robert Esnault-Pelterie has been working on these problems since 1913. In the United States Robert Goddard began a great work on rocket propulsion which lasted many years, and in 1923 in Munich Hermann Oberth published a pamphlet *Rocket in interplanetary*

[18] Ibidem, p. 258-260.

space. His later research and efforts contributed greatly to the realization of the idea of rocket propulsion.

In the beginning not one of the above named research workers did mention in his works the name of Ciołkowski, though many of their attainments were known to the Russian scientist years before and were made known in his books. It is not possible to suspect all of them of plagiarism. It was probably a case such as occurred to Ciołkowski in the beginnings of his scientific work, namely when he obtained independent results, which were also well known years before.

This misunderstanding, if misunderstanding it was, has been cleared in 1924 when the work of Ciołkowski, written in 1903, has been published with a foreword in German by A. L. Tchijewski and the priority of Ciołkowski in many questions concerning astronautics has been established. In the following years the basic works of Ciołkowski have been translated into German.

Today the name of Ciołkowski may be found in almost all works dealing with the problems of astronautics on a place of honour as that of a man who laid the foundations to this branch of science and technology [19].

In 1929 Oberth in a letter acknowledging the receipt of some material wrote: "I am certainly the last to question your priority or your merits in the matter of rockets and I am but sorry that it came to my knowledge only in 1925. I would have made much more progress in my problems and would have saved much work had I known your excellent works" [20]. In another letter Oberth wrote: "You lit the fire and we shall not let it extinguish, so that the great dream of mankind may be realized" [21].

The last years brought us nearer to this dream and the years to come shall certainly witness its realization.

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[19] Compare the above named book by W. Ley and the following books: *Träumer-Forscher-Konstrukteure* by Heinz Gartmann, Düsseldorf, 1954, *Die Welt wird grösser* by Gerhard Lau, Lahr Schwarzwald, 1956. But W. Gatland in his book *Development of the Guided Missile*, (London 1954) does not even mention the name of Ciołkowski, giving the twenties of the current century as the period when the theoretic bases of cosmic flights were born.

[20] After the edition *Ludi russkoy nauki* vol. II, Moscow—Leningrad 1948, p. 1043.

[21] Ibidem.